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Direction Studies Using Microseim Ground-Particle Motion

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Directicn Studies Using Microseim. Ground-Particle Motion

by

William L. Donn

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ABSTRACT

Ground-particle trajectories were constructed for Palisades microseims originating in storms having various positions and azimuths with respect to the continental margin. It was found that good directional success was obtained for sources on the continental shelf or for deep-water storms on an azimuth normal to the continental margin. The complete lack of directional relationship between particle motion and source direction for deep water sources having azimuths oblique to the coast is ascribed to simple refraction or interference between waves having multiple refraction paths. Microseisms arriving at Palisades with 8 to 9 sec period and 1 to 2 microns ground amplitude have been traced back to North Pacific sources more than 5000 km away. Very good directional correlation was obtained in these cases between ground-particle motion and source direction. The results of the study appear to explain the original tripartite success of Ramirez in obtaining good locations for Atlantic storms.

INTRODUCTION

Determinations of the directions of microseism-generating sources by means of tripartite and Rayleigh-wave techniques (1,2,3,4) have generally proven inadequate. The sources studied in the past were tropical or extra-tropical cyclones over deep water beyond the edge of the shelf. It was concluded (1, 2) that refraction at the continental margin, in addition to the presence of broad or multiple source areas, were the main causes of failure not inherent in the procedure. It was argued from this that better correlation with direction should be obtained using microseisms from limited generating areas on the continental shelf, where the effect of the margin is eliminated, and from distant storms whose azimuths from the station are fairly normal to the coast.

Since Rayleigh-wave motion was demonstrated for Palisades microseisms (2), it was concluded that the above ideas could be checked by determining ground-particle motion from matched three-component seismographs, and by noting in particular the projection of this motion in the horizontal plane. For most of the cases the Palisades Benioff Seismographs ($T_o = 1$, $T_g = 75$) were used. In two cases the Palisades

Columbia instrument (T_0 =12, T_g =15) were used, owing to their higher magnification. The appropriate instruments are designated in each case.

The theoretical errors involved in the procedure of azimuth determinations from horizontal trajectories originates in instrumental and reading errors. The former depends on variations from expected phase response, magnifications and drum speeds. Reading errors result from inaccuracies in time and amplitude measurements on the records and from estimations of the exact elongation directions of the orbits. The reading errors can be evaluated more definitely than those of instrumental origin. It is estimated that the maximum theoretical error, if the causes are cumulative, could be from 50 to 75 degrees. However, the consistency of the results to be given below indicates that operation was well within the theoretical error as a result of the great care taken and compensating effects.

MICROSEISMS FROM CONTINENTAL SHELF SOURCES

Figs. 1 and 2 show two different cold fronts extending in a northeast-southwest direction over local shelf waters. As a result of the frontal alignment and the coastal configuration in the vicinity of Palisades (P), the area of microseism generation between the cold fronts and the coast is quite restricted in size and is limited to a sector between south and southeast of Palisades.

Thirty microseism groups, which were particularly coherent and prominent on the vertical records and which were readily identified on the horizontals, were selected for measurement from the microseism storm corresponding to conditions shown in Fig. 1. These were short-period microseisms (3 sec) and were completely typical of all frontal microseisms recorded and studied at this station. Phase relations among the three components were proper for Rayleigh-wave motion. Horizontal ground-particle trajectories were constructed from the Benioff seismograms for the maximum wave from each of the thirty groups. This motion is reproduced in Fig. 3. Most of the orbits show pronounced elongation and are aligned SSE-NNW. A comparison of phases between the vertical and horizontals indicates that all motion was from the SSE. Hence all but the second of the orbits point directly into the frontal or post-frontal zone. In cases where there is departure from good elongation, a recheck of the records showed that the waves in these cases were not as coherent on the horizontals as the visual inspection, on which selection was based, seemed to indicate. The more coherent the wave, the better is the approach to linearity for the horizontal orbit. The mean azimuth of the trajectories is 157 degrees, with a standard deviation of 15 degrees. This error is expected in view of the errors considered above and the broad sector of approach owing to the proximity of even this small generating area.

A second case of typical frontal microseisms was studied for the cold front shown in Fig. 2. The selection of microseisms was similar to the above case except that every wave in each of nine good groups was measured, giving a total of fifty waves. The horizontal trajectories (from the Benioff seismographs) are shown in Fig. 4, where the orbits from each wave are separated for ease of study. Good elongation is again shown with little scatter from a SSE-NNW direction. All waves arrived from the SSE. The mean azimuth for this set is 166 degrees with a standard

deviation of 10 degrees. The smaller deviation in this case is probably a result of the greater microseism amplitudes which permitted measurement with greater accuracy.

Again, the waves whose orbits are irregular or exhibit poor elongation show poor coherence when examined carefully. It is a simple matter to select the orbits which may be expected to give the most reliable direction determinations.

MICROSEISMS FROM DISTANT ATLANTIC STORMS

Fig. 5 shows a large, intense cyclone extending from the coast to deep water. A very intense microseism storm was recorded at Palisades at this time. Again, on the basis of visual coherence a single wave from each of the twenty-eight good groups was selected for measurement from the Benioff records. Although the dominant microseism groups consisted of waves with about 8 sec period, the record was irregular owing to the presence of lower-amplitude, shorter-period microseisms. The association of broad period spectra with storms having considerable variation in depth has already been demonstrated in detail (5). It is emphasized here that only the dominant microseisms were utilized in construction of trajectories.

The trajectories for the twenty-eight waves selected are shown in Fig. 6. Although they have a definite tendency toward elongation, the ellipses are much distorted, and show considerable scatter in their alignment directions. The approach azimuths determined by comparison of vertical with horizontals are indicated by the short arrows external to the orbits. In some cases

no directions could be determined. A considerable diversity in travel direction is indicated, with no approach from the east, the direction of the cyclone! If the long-period microseisms originated in the region of the steep pressure gradient around the cyclone center, or nearly due east of Palisades, those traveling toward the station would have entered the continent at a very high angle of incidence, thereby suffering considerable scatter and refraction. There is also the possibility that waves traveling multiple refraction paths would arrive at the station simultaneously. These propagation factors could explain the diversity in azimuths given by the horizontal orbits.

Fig. 7 illustrates another strong cyclone nearly due east of Palisades. Fig. 8 reproduces the horizontal trajectories from seven good wave groups on the Benioff records. Although many of the orbits show good elongation in the horizontal plane, none of them show any alignment in the direction of the storm azimuth. The quadrants of approach are indicated by the arrows at the end of each group. The data from these two storms is quite typical of that obtained from cyclones in this position. The lack of any indication of approach from the storm together with the great diversity in direction is certainly of significance in considering microseism propagation.

Figs. 9 and 10 show two cyclones centered northeast of Newfoundland and situated on an azimuth from Palisades that is essentially normal to the coast. Figs. 11 and 12 show respectively the horizontal trajectories for the microseisms associated with each of these cyclones. The orbits represent continuous waves in the groups illustrated and were constructed from the Benioff records. The average period from both cases was from 5 to 7 sec. Most of the orbits in both cases show good elongation. Badly distorted ellipses can again be traced to waves that show definite departure from coherent sinusoidal form. All the waves in each case were determined to approach from the northeast quadrant. There is also considerably greater uniformity in the orientation directions shown here, than was exhibited by the two previous cases.

The azimuth of the cyclone center in Fig. 9 is 44 degrees. The mean azimuth determined from the orbits showing good elongation in Fig. 11 is 42 degrees with a standard deviation of 19 degrees. Since the microseism source region is assumed to be not the center but the region of steep pressure gradient surrounding the center, the sector subtended at Palisades by the generating area would lie

within and actually be about equal to the standard deviation sector.

The mean azimuth for the cyclone center shown in Fig. 10 is 34 degrees. The mean azimuth determined from the orbits showing good horizontal elongation is 38 degrees with a standard deviation of 17 degrees. The intense part of the cyclone area assumed to be the source region again subtends a sector at Palisades that about equals the standard deviation sector. The difference in direction correlations between these and the preceding two cases seems to arise from the differences in storm positions relative to the continental margin.

MICROSEISMS FROM DISTANT PACIFIC STORMS

Palisades occasionally experiences long-period microseisms (8 to 10 sec) characteristically different from those commonly associated with the frequent intense cyclones in the North Atlantic. These different microseisms arrive in long groups often of several minutes duration, the waves of which show almost constant amplitude compared to the typical growth and decay pattern shown by the more common groups from Atlantic sources. There is a complete absence of short-period microseisms, and usually pronounced quiet intervals between groups. Direction studies were made for two such cases and indicated sources in the northeast Pacific Ocean. Ground amplitudes for these two microseism storms were from 1 to 2 microns at Palisades.

The Palisades Columbia instruments were used for this purpose since their higher magnification permitted better measurement than did the Benioff. To verify the theoretical calibration of these instruments for the periods being studied, Rayleigh waves R_g (6) from the Alaskan shock of May 25, 1950 (Azimuth=327°, Δ =5369km) were studied and horizontal trajectories constructed.

The periods of 9 to 12 sec were very close to those of the microseisms under consideration. Horizontal trajectories for these earthquake waves are reproduced in Fig. 13. The mean azimuth of this group is 337 degrees which gives good success for the location of the epicenter considering the admissable error in procedure.

Horizontal trajectories from the prominent long-period microseism storm of March 29-30, 1953 are shown in Fig. 14. Most of the orbits show very good elongation and fairly consistent alignment directions. The mean azimuth of all of the orbits is 322 degrees, with a standard deviation of 17 degrees. The North America weather chart in Fig. 15 shows an intense cyclone south of Alaska which has a center azimuth of 319 degrees from Palisades! The standard deviation for the computed azimuth can be reduced by selecting only the most nearly linear orbits in Fig. 14. The distorted or rather circular orbits in Fig. 14 can conceivably result from interference between the Alaskan storm microseisms with those from some other direction, in this case possibly the region of the steep pressure gradient north of Canada. Similar effects have been observed at Tokyo (7) where there are often steep pressure gradients at many azimuths.

Trajectories were also constructed from the records of the U. S. Coast and Geodetic Survey seismograph in Chicago.

These gave a mean azimuth of 334 degrees. The difference between this and the Palisades determinations is certainly in the right direction since Chicago is about 800 miles west of the former station. In addition these microseisms have been clearly identified on the records of Sitka, Denver, Cincinnati and Cleveland, the identity being based on simultaneity of events and microseism period, the latter varying by no more than 1 sec at the six stations.

Fig. 16 shows the trajectories for the long-period microseism storm of January 31-February 1, 1953. Again the trajectories show marked elongation and fairly constant orientation. These orbits have an average azimuth of 322 degrees with a standard deviation of 14 degrees. Weather maps for this time show an intense cyclonic area with steep pressure gradients extending from the Aleutian Islands southeastward to the Canada-United States border.

CONCLUSIONS

Good directional correlation exists between microseism approach direction as determined from ground-particle motions, and direction of the source when the source is either on the continental shelf or on an azimuth normal to the continental margin. When the source is in deep water and on an azimuth oblique to the coast there seems to be no correlation between particle motion and source direction. This is interpreted as a consequence of either simple refraction at the continental edge or a combination of refraction and interference between waves having multiple refraction paths.

It seems most significant that microseisms propagate across more than 5000 km of continent with relatively small attenuation and that good directional correlation exists after long continental propagation between ground-particle motion and cyclone direction. A relationship is suggested between these microseisms and the short-period surface waves (R_g) which appear to have propagation characteristics of refraction and continental preference similar to those of microseisms.

It seems evident from this study that tripartite procedures can only be successful under certain conditions and could not be generally applicable even assuming that all other defects in the procedure were eliminated.

Ramirez' success (8) in obtaining good tripartite directions on Atlantic storms appears explainable by this study. At least half of the hurricane he tracked moved northward on the continental shelf. Further, other larger cyclonic areas he located were either on the shelf or on an azimuth fairly normal to the coast, and some were in the same positions as those for which good locations were obtained in this study. The effects of long continental paths may also have been of importance in minimizing refraction problems.

ACKNOWLEDGEMENTS

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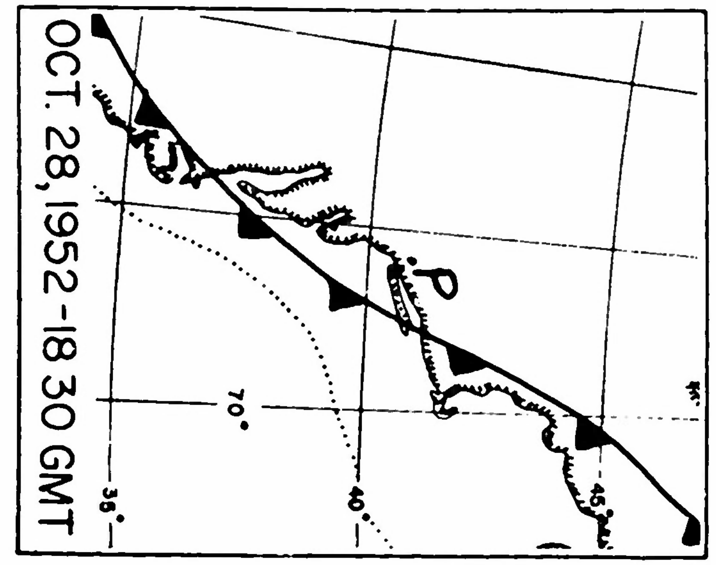
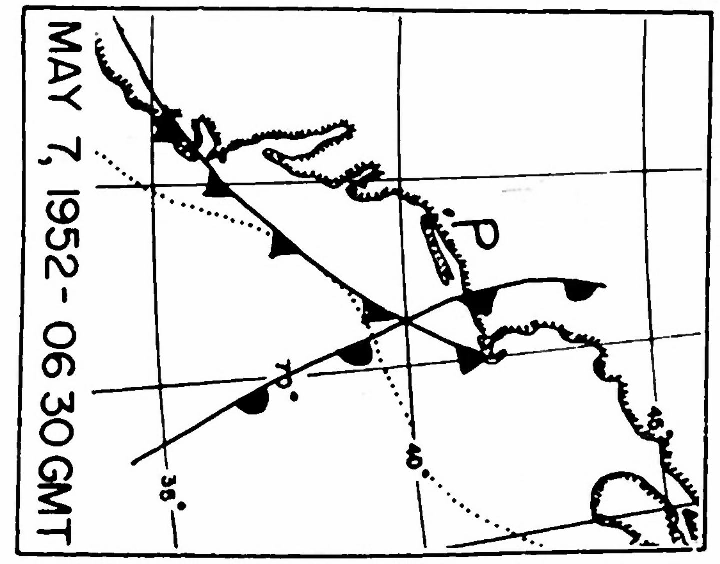


Figure 1.



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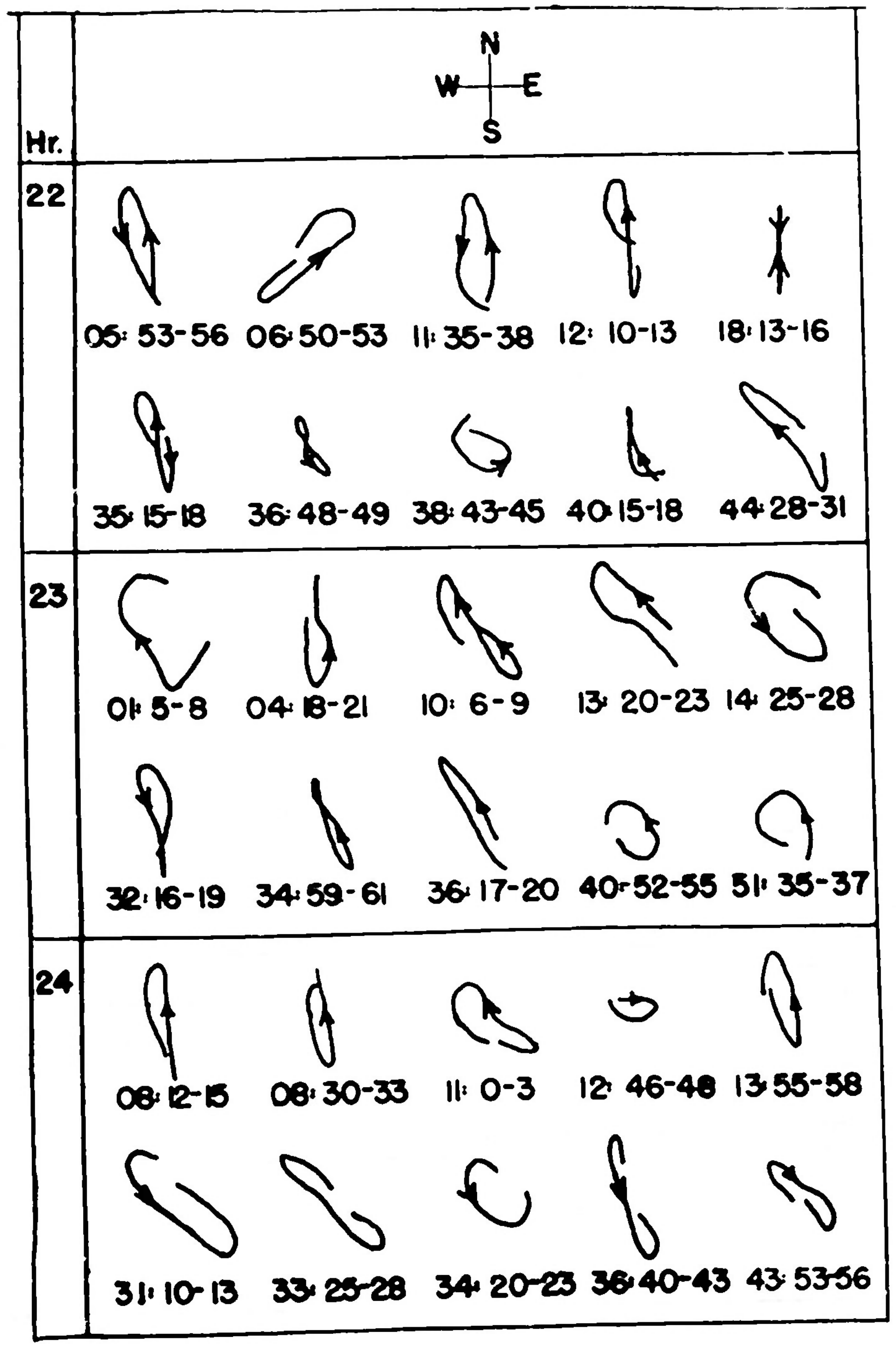


Figure 3. Horizontal Trajectories from Palisades Benioff Seismograph for October 28-29, 1952.

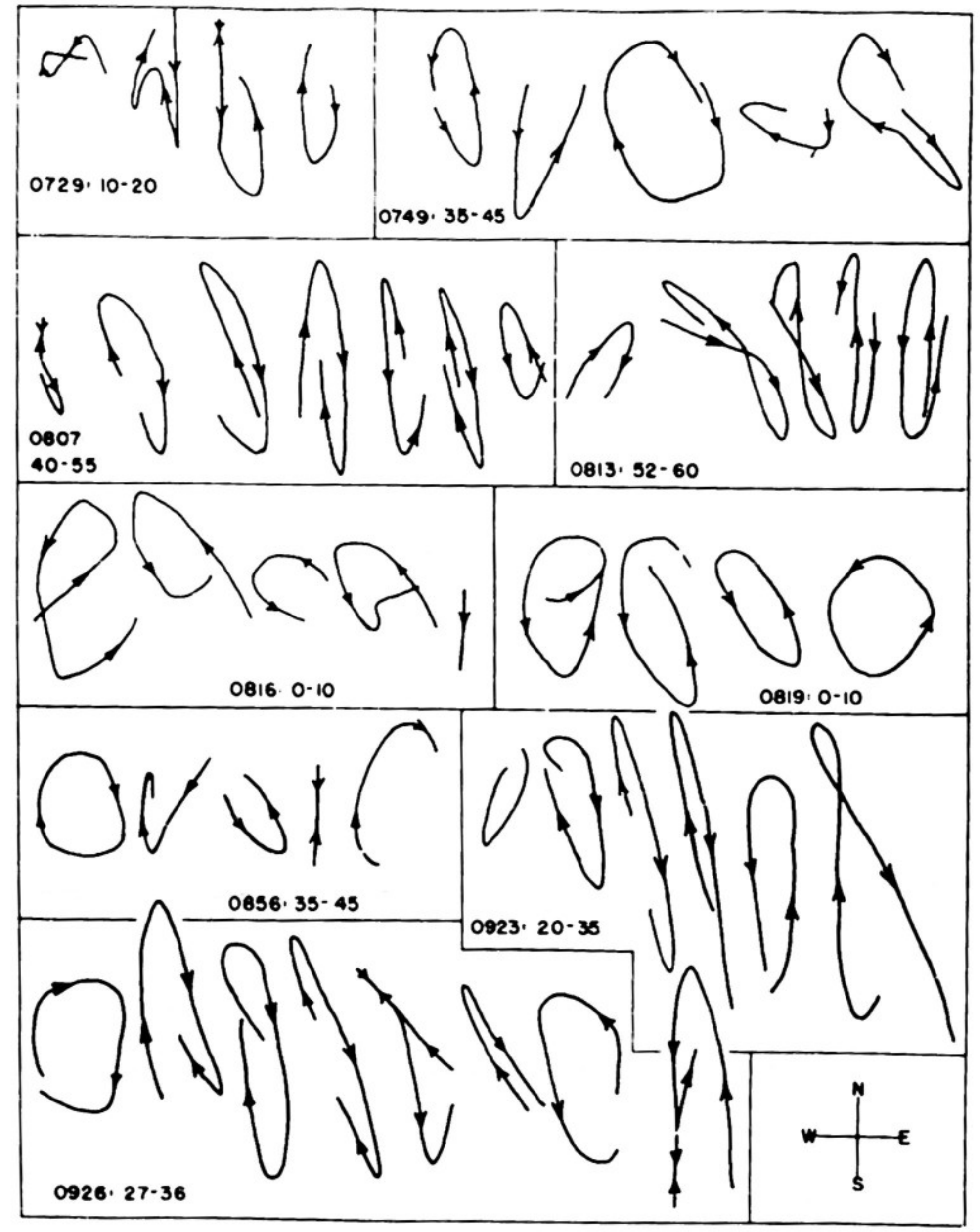
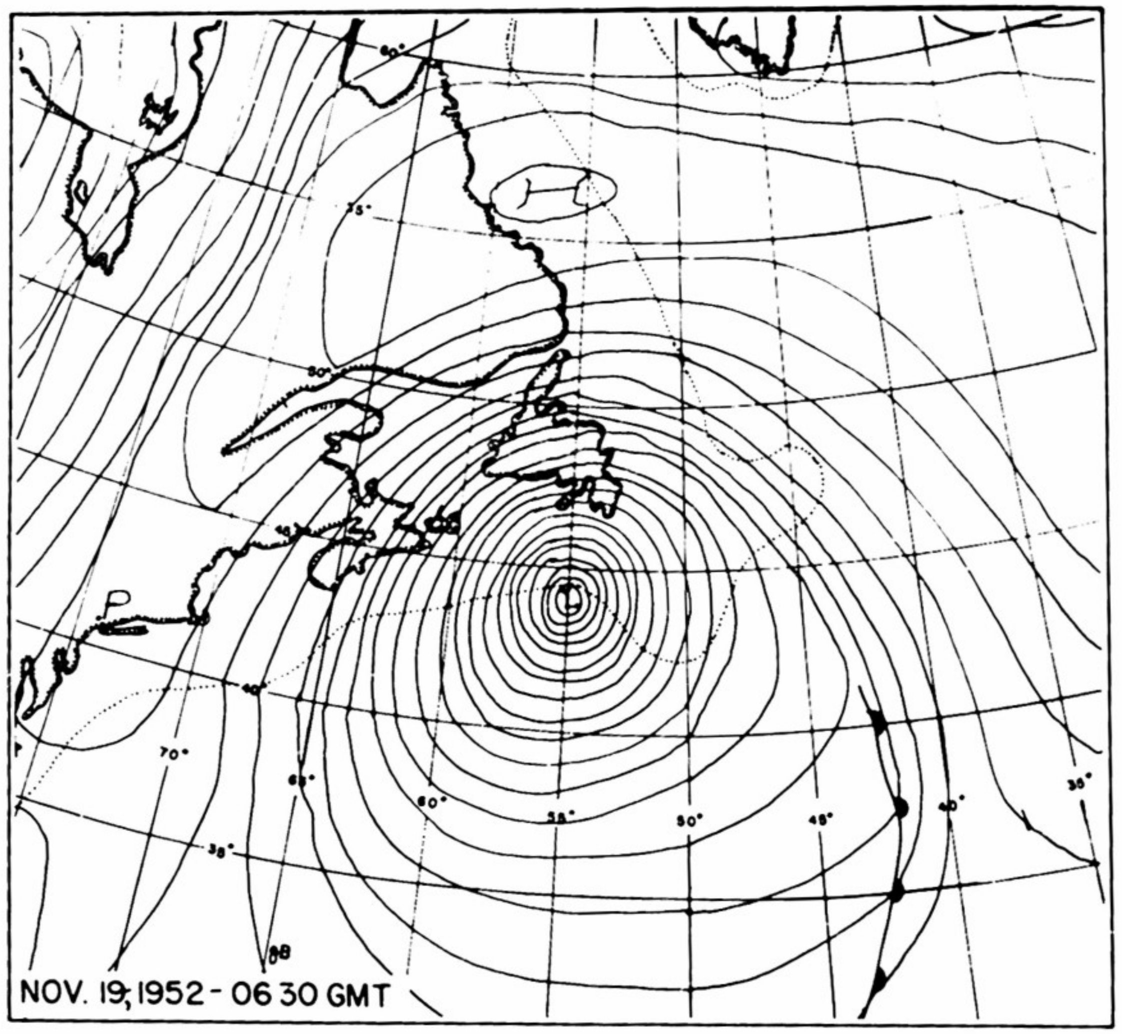


Figure 4. Horizontal trajectories for May 7, 1952.



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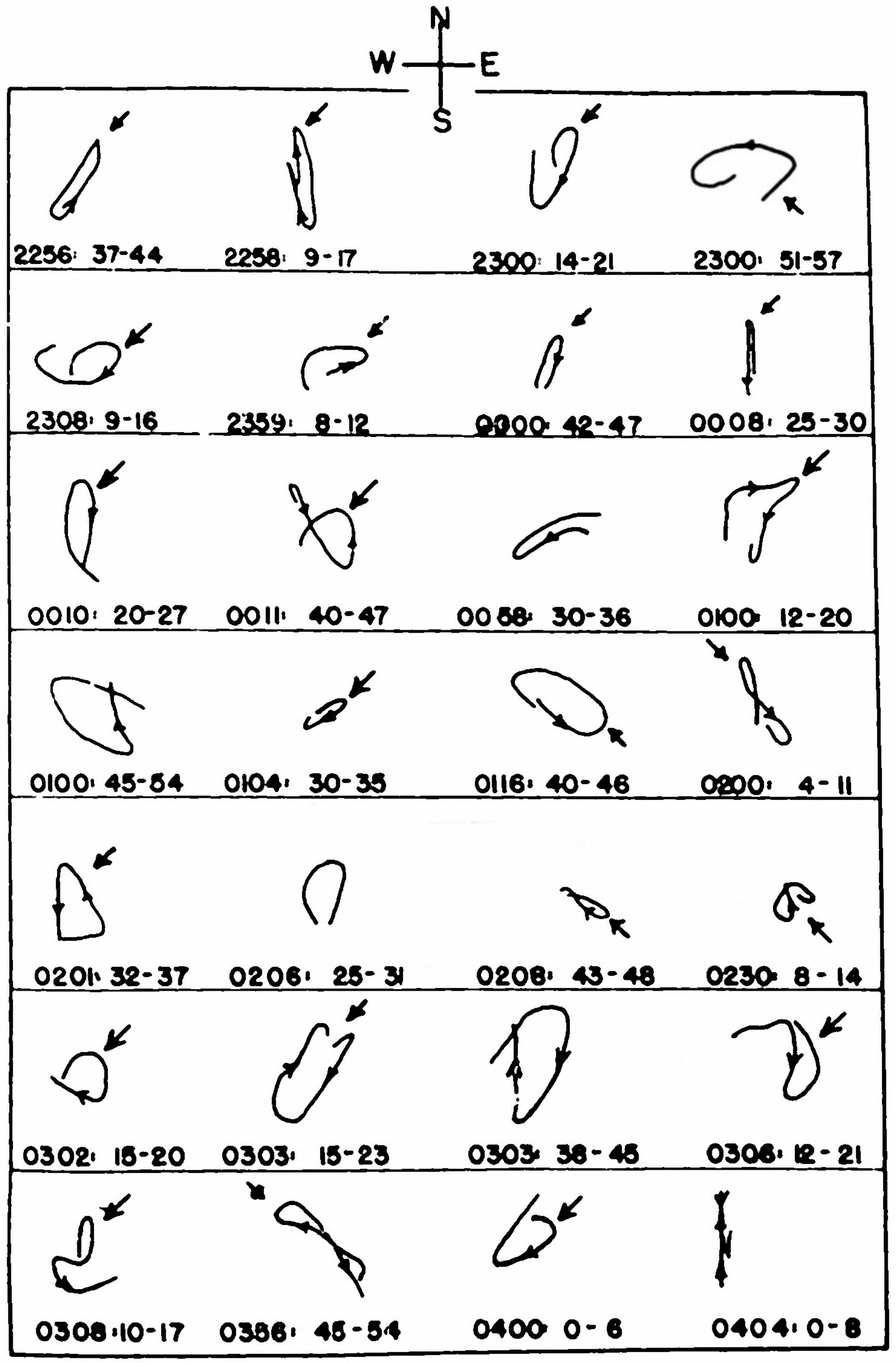


Figure 6. Trajectories for November 18-19, 1952.

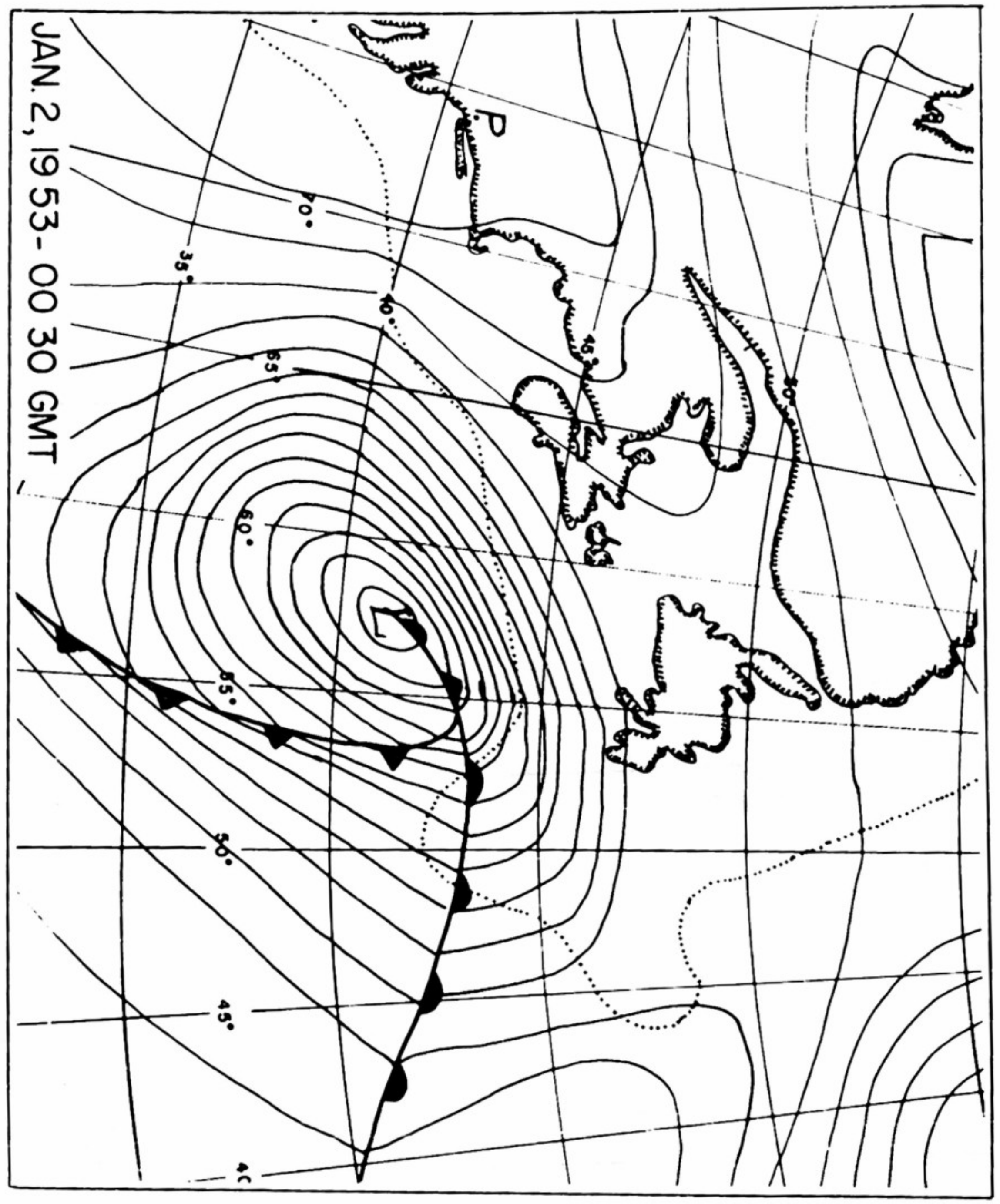


Figure 7.

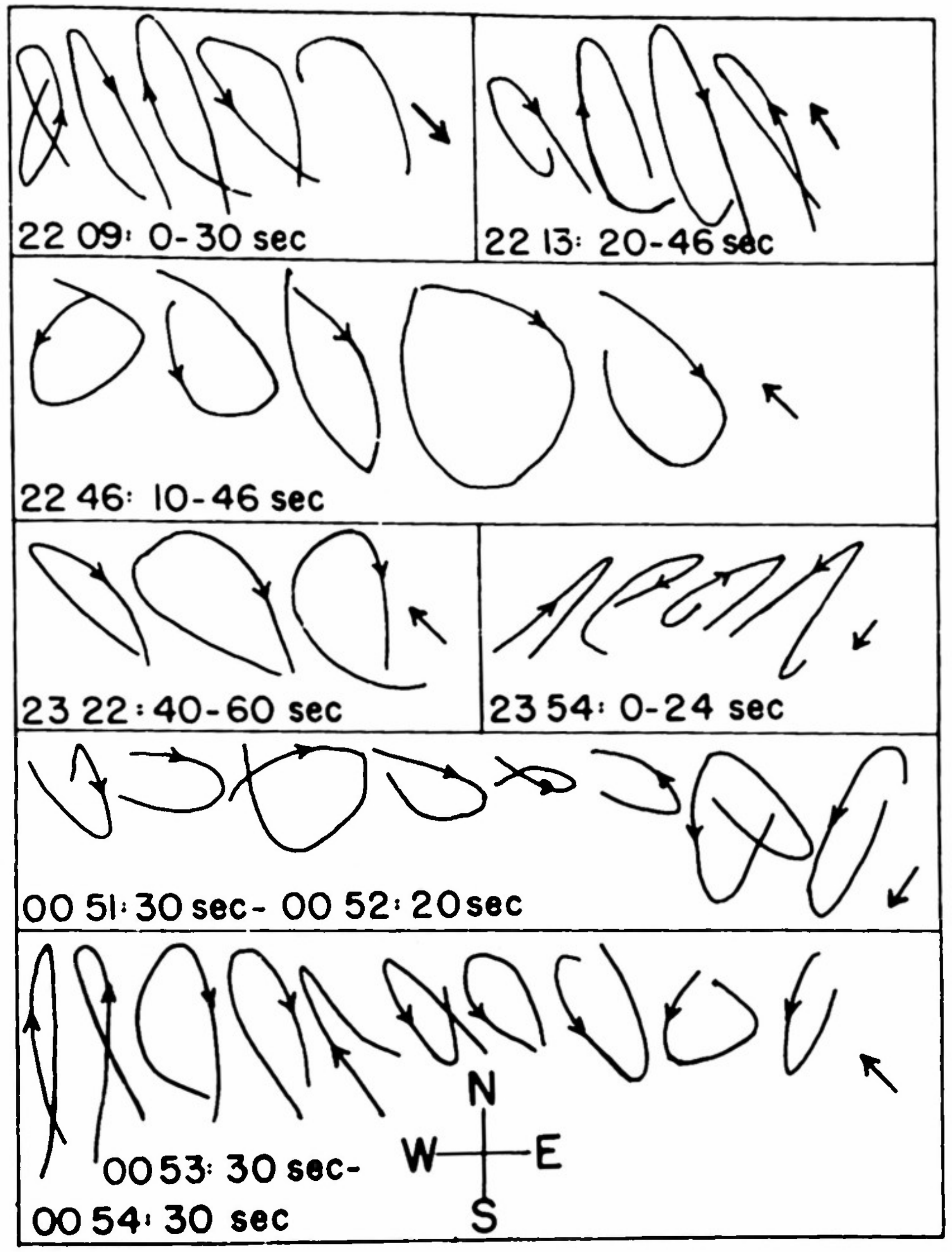


Figure 8. Trajectories for Jan. 1-2, 1953

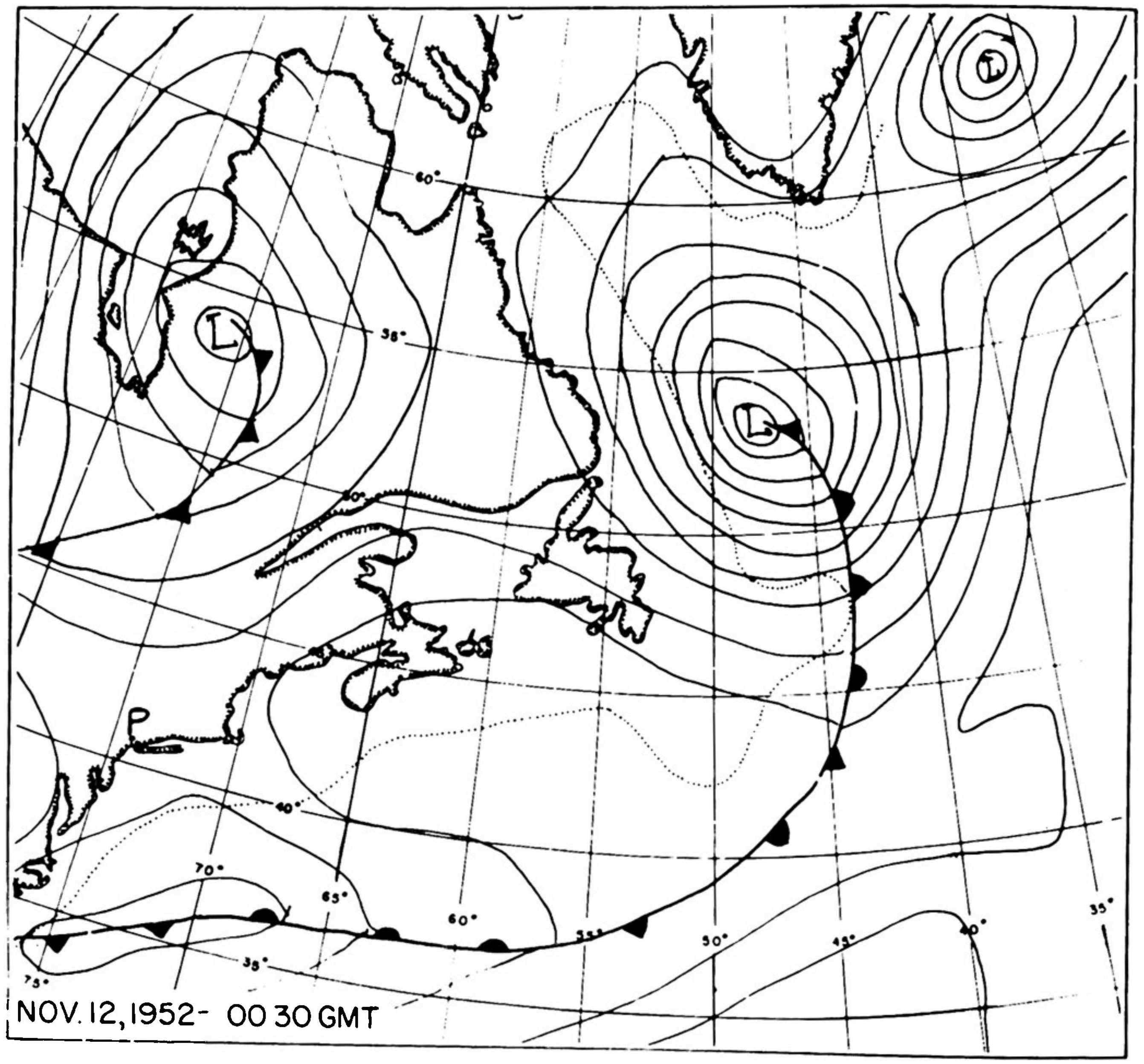


Figure 9.

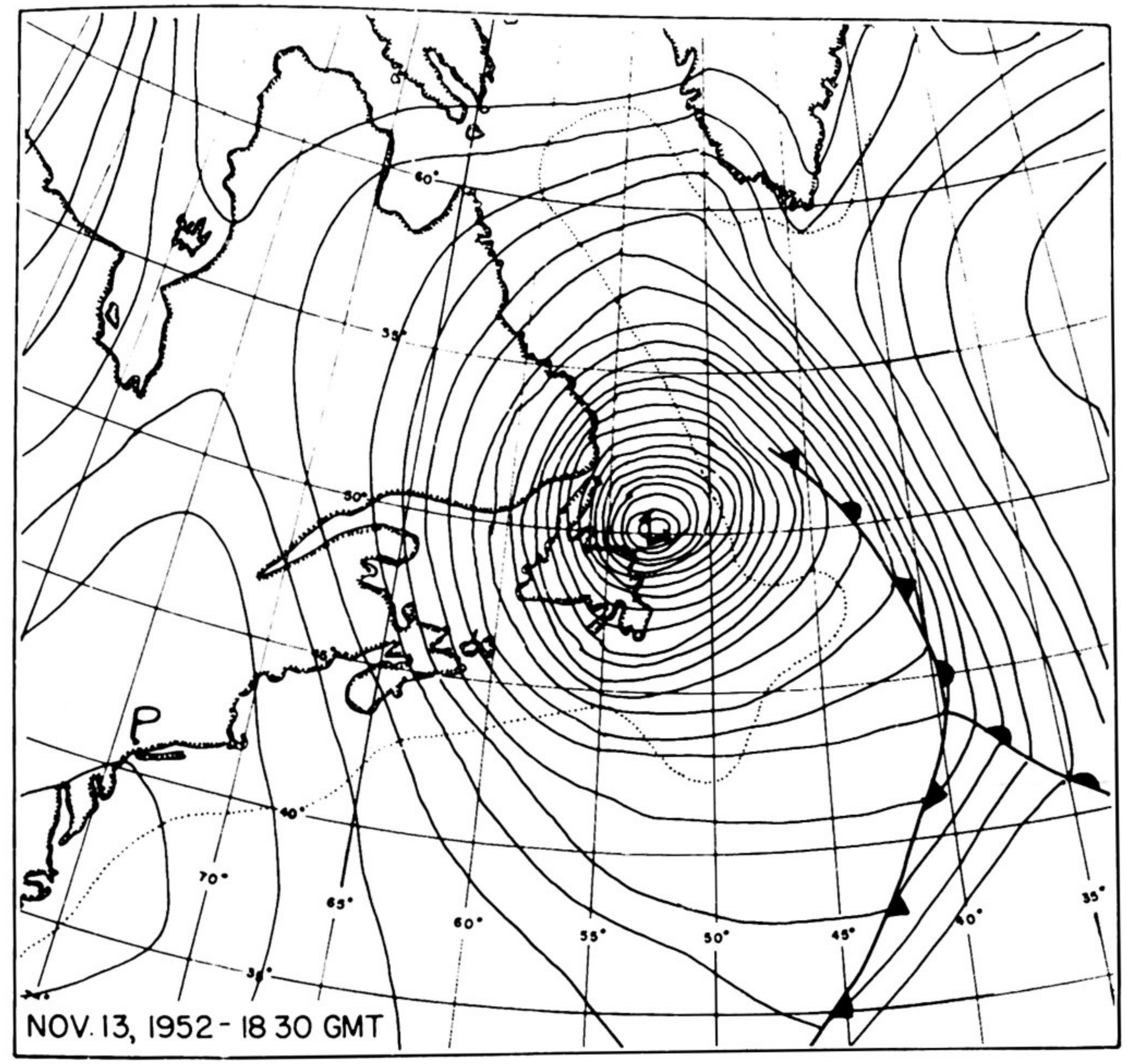


Figure 10.

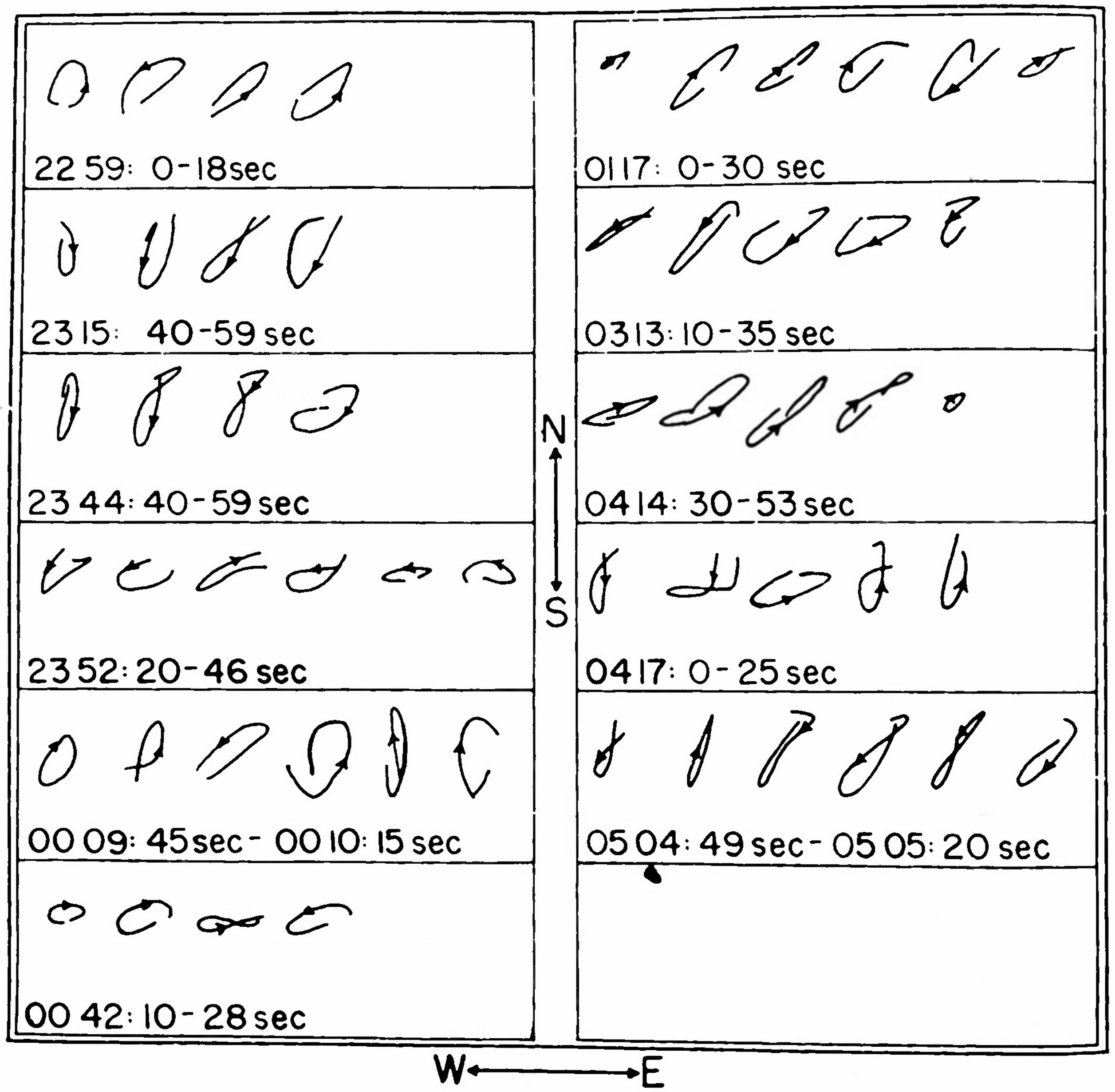


Figure 11. Trajectories for November 11-12, 1952.

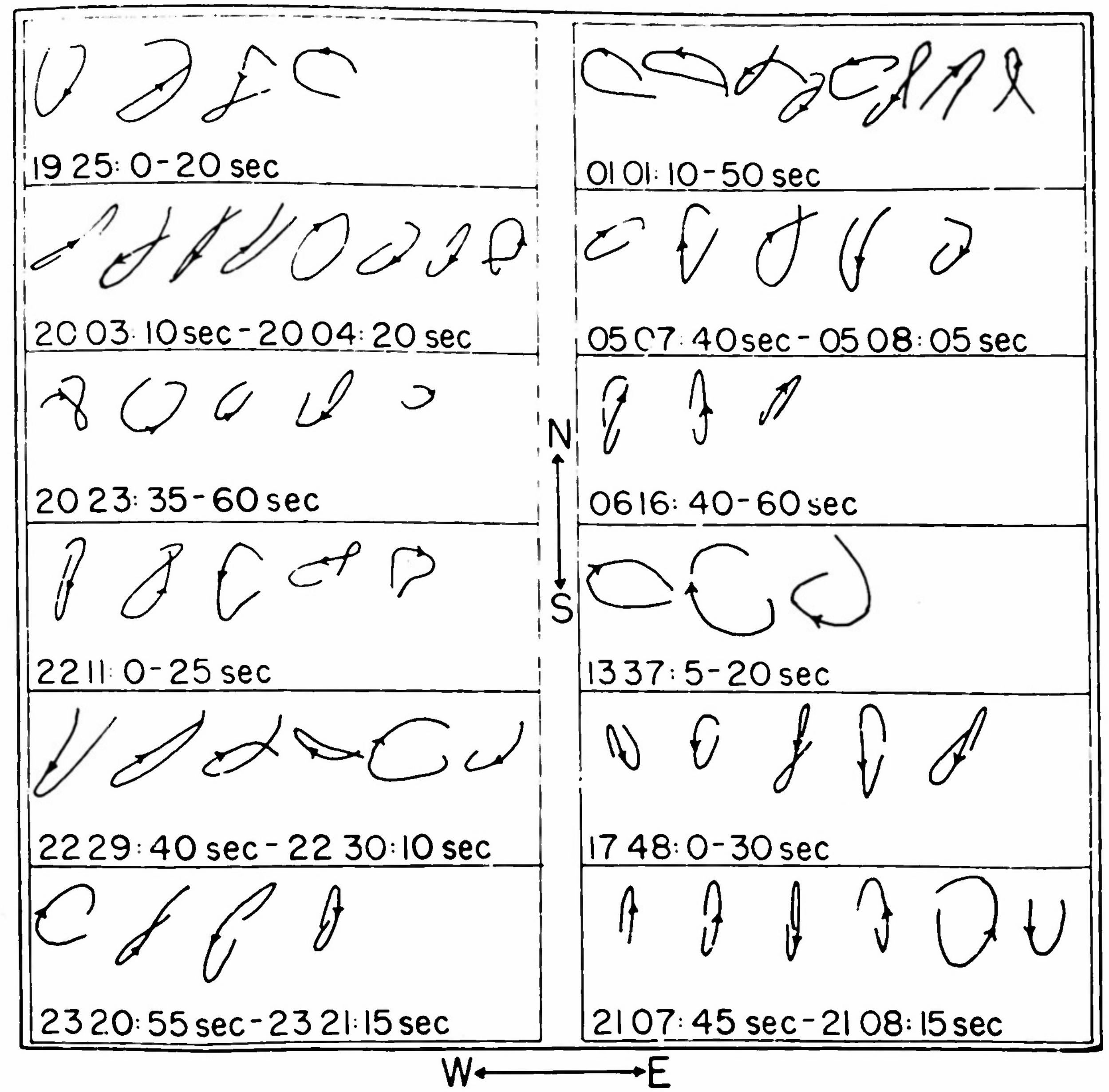


Figure 12. Trajectories for November 13-14, 1952.

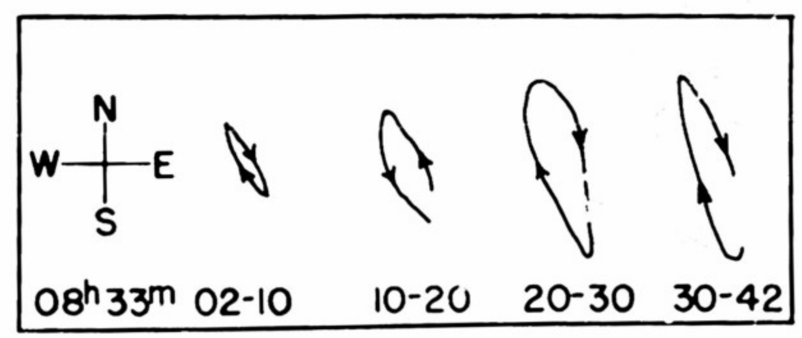


Figure 13. Horizontal trajectories from Palisades Columbia Seismograph for Lg from shock of May 25, 1950.

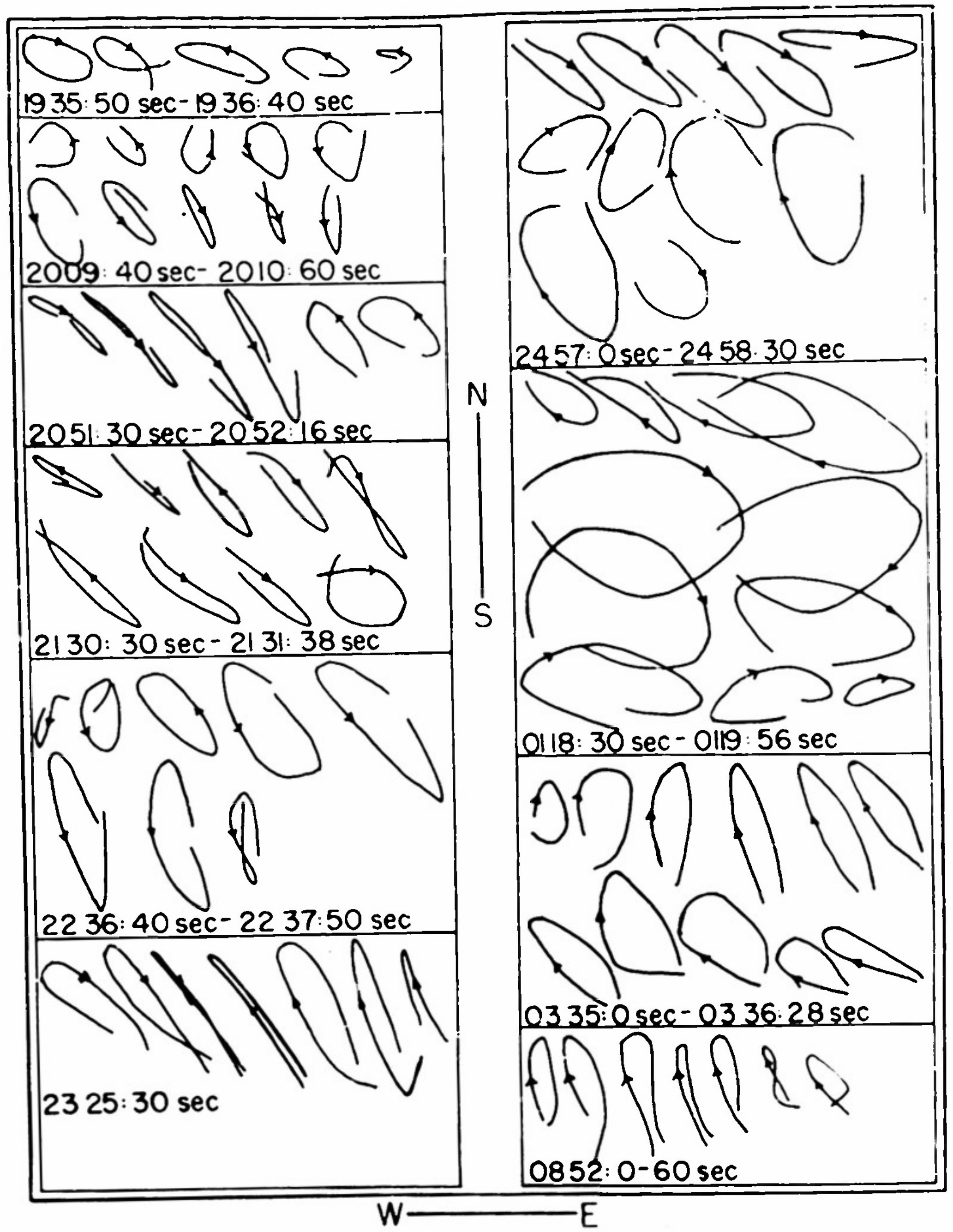
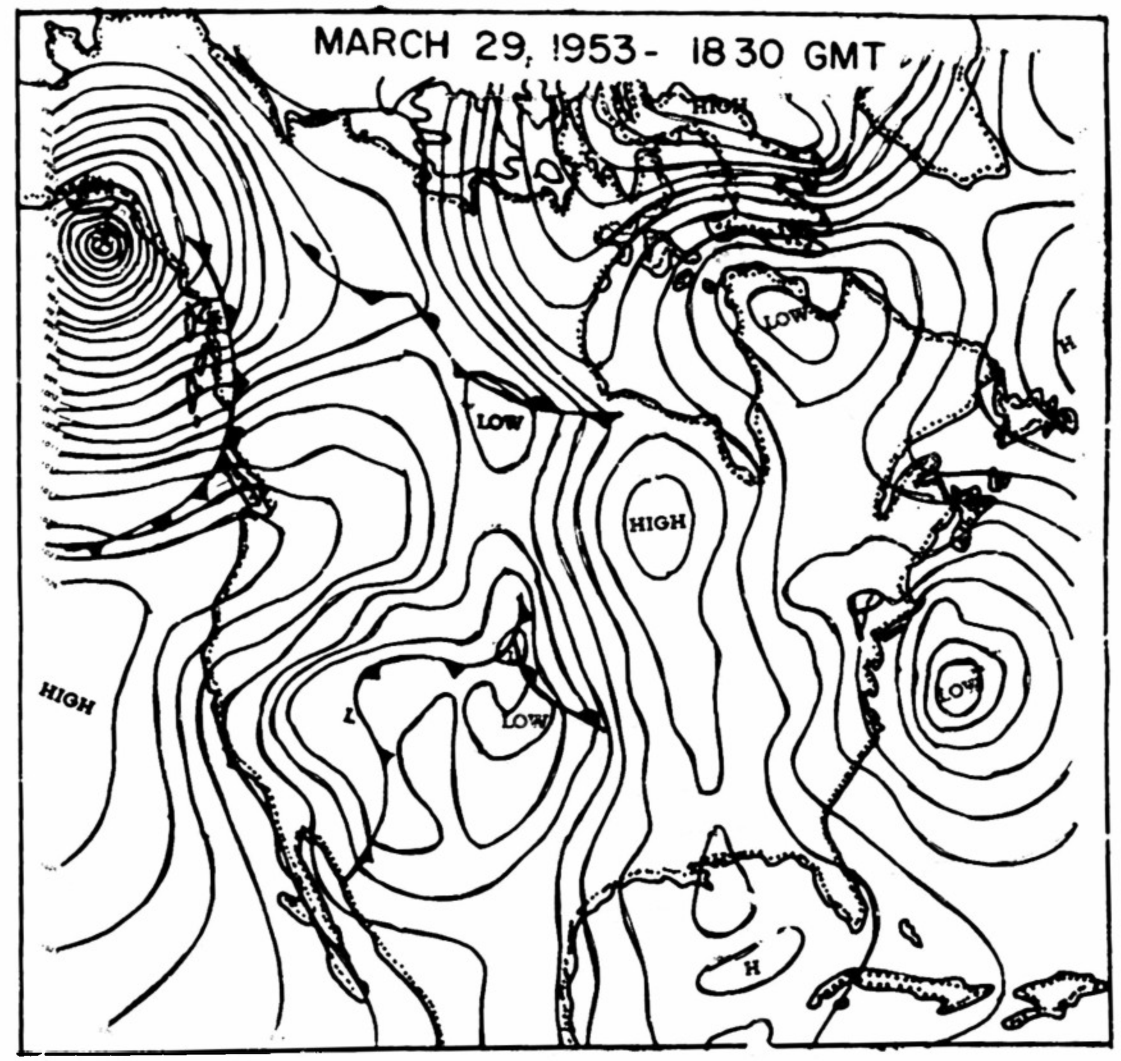


Figure 14. Trajectories for March 29-30, 1953.



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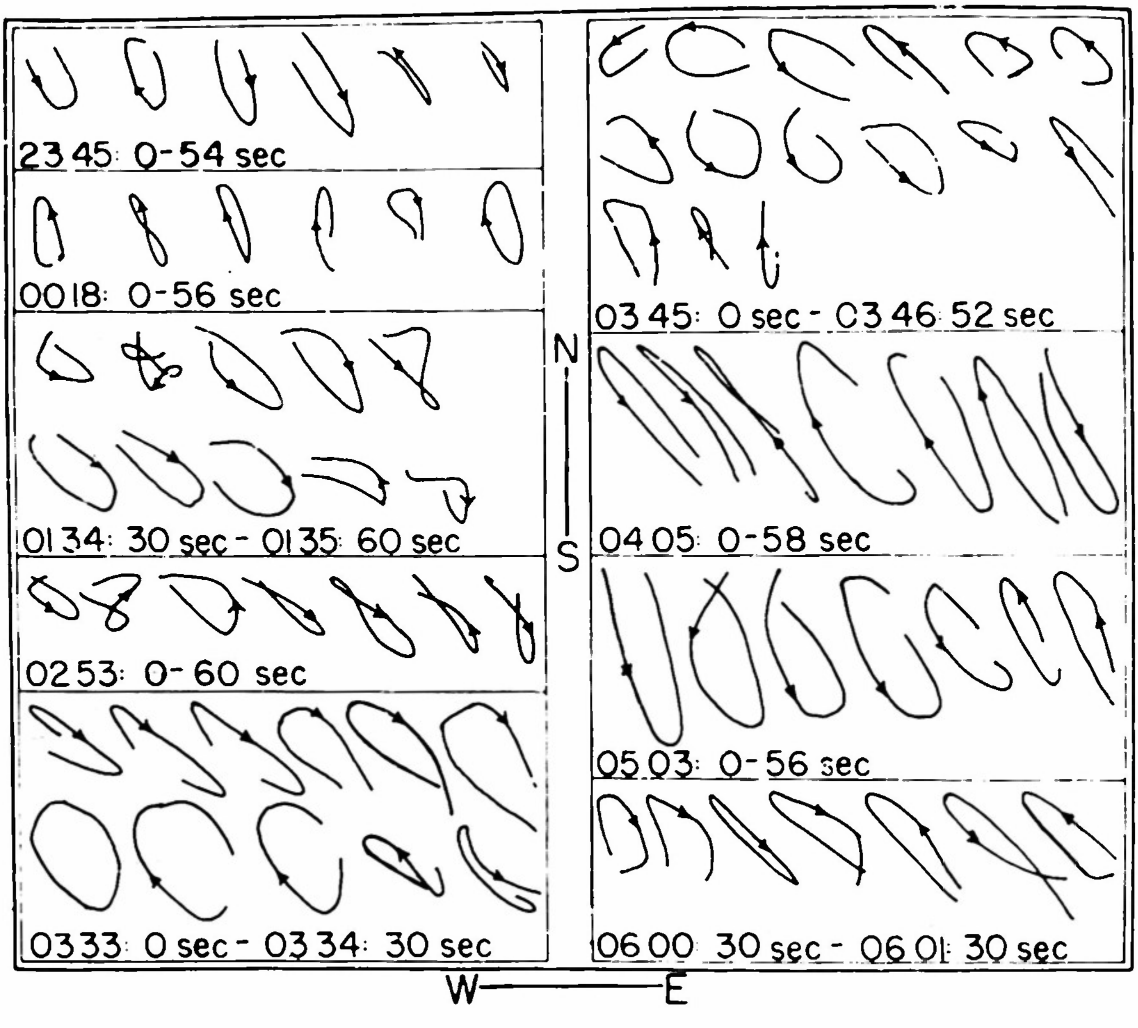

Figure 16. Trajectories for Jan. 31-Feb. 1, 1953